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Abstract

**UO₂ PERFORMANCE - THE IMPORTANCE OF
TEMPERATURE DISTRIBUTION**

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1. The performance of UO₂ fuel elements is largely determined by the temperature distribution in the fuel. On this factor depend the disposition of the fuel, its expansion behaviour and the pressure developed by released fission-product gases.
2. Irradiated UO₂ pellets frequently exhibit cracks induced by thermal stresses. Pellets irradiated with preformed cracks demonstrated that healing occurs out to a radius slightly greater than that for just-discernible grain growth in the UO₂. Within this region large cavities closed during irradiation, but they remained unchanged in the outer annulus. Tungsten markers have confirmed that columnar grains can form below the melting point. Those columnar grains that are formed by freezing are identified by their characteristic structures of sub-grain boundaries and pores.
3. From 400 to 1600°C the mean value for the thermal conductivity of sintered UO₂ during irradiation is 0.03 W cm⁻¹ degC⁻¹, deduced from thermocoupled elements and observations of grain growth. At higher temperatures, the interpretations of melting lead to a mean value of 0.035 W cm⁻¹ degC⁻¹ affected little, if any, by grain growth. Following an irradiation demonstrating the relatively poor thermal conductivity of UO_{2+x}, simple comparative tests in the laboratory suggested that UO_{2-x} has improved conductivity. In a subsequent irradiation the central temperatures in UO_{1.98} specimens were as much as 100 degC lower than those of UO_{2.007} controls at 1200°C. Potentials measured between the fuel centre and surface showed that hypostoichiometric urania is an n-type conductor (hyperstoichiometric urania is p-type).
4. Post-irradiation collection of the released fission-product gases, supplemented by analyses for radial distribution of the gas remaining, confirmed that the overall release process is thermally activated. Comparison of elements irradiated alongside each other has shown a progres-

sive decrease in release with increasing density in the range 10.4 to 10.75 g/cm³. Measurements made during irradiation indicated that the gas pressure can decrease markedly with minor sheath strain due to fuel expansion.

5. Post-irradiation observations on elements containing internal gauges defined conditions for which a stack of cylindrical UO₂ pellets is restrained from expanding thermally into an end-clearance. Measurements during irradiation showed how restraint can cause plastic deformation of the UO₂ at temperatures over approximately 750°C. A "plastic-core" model for the fuel can also explain the diametral expansion of the UO₂, which is typically 2.2% of the diameter at the onset of central melting. Thereafter, an increase in the rate of diametral expansion with power output is attributable to the volume change on melting.
6. At the 1958 Geneva Conference, an $\int_{\text{surface}}^{\text{centre}} \lambda d\theta$ value of 40 W/cm (λ is the thermal conductivity of the fuel at temperature θ) was recommended for sintered UO₂ in water-cooled power-reactors. The acceptability of thin, collapsible Zircaloy sheaths was subsequently established in tests taken to 10 000 MWd/tonne U. Experiments with $\int \lambda d\theta$ values up to 85 W/cm have now indicated the feasibility of operating power-reactor fuel up to 50 W/cm.